Enhancing Resource Allocation In Edge Computing For Metaverse With Blockchain And DQN

An Internship Report

submitted in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

COMPUTER SCIENCE & ENGINEERING

Submitted by

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DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

LAKIREDDY BALI REDDY COLLEGE OF ENGINEERING

(AUTONOMOUS**)**

Accredited by NAAC with 'A' Grade & NBA (Under Tier - I)

An ISO 21001:2018, 14001:2015, 50001:2018 Certified Institution

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2024-2025

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DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING

CERTIFICATE

This is to certify that internship work entitled **"Enhancing Resource Allocation In Edge Computing For Metaverse With Blockchain And DQN"** the bonafide work done by **LAGHUVRAPAU JYOTHI PRAKASH (21761A05A2)** in partial fulfillment of the requirements for the award of the degree in **BACHELOR OF TECHNOLOGY** in Computer Science and Engineering from **LAKIREDDY BALI REDDY COLLEGE OF ENGINEERING, MYLAVARAM** during the year 2024-2025.

D. Anil kumar
(Internship Coordinators)

Dr. D. Veeraiah
(Head of the Department)

EXTERNAL EXAMINER

CERTIFICATE OF COMPLETION

Malaviya National Institute of Technology Jaipur
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Internship Training Certificate

This is to certify that **Laghuvarapu Jyothi Prakash (21761A05A2)** of Department of Computer Science and Engineering, Lakireddy Bali Reddy College of Engineering, Mylavaram, NTR District, Andhra Pradesh has been completed the training and the research internship project on "***Enhancing Resource Allocation In Edge Computing For Metaverse With Blockchain And DQN*** " under my supervision. Duration of the training was from **15 May'2024 to 30 June '2024**. He has successfully completed above internship work and his performance was excellent during training period.

I wish his bright future ahead.

Date: 30th June 2024

MNIT jaipur

B. Ramesh Babu

Dr. Ramesh Babu Battula

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L JYOTHI PRAKASH

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DECLARATION

We hereby declare that the project report entitled "**Enhancing Resource Allocation In Edge Computing For Metaverse With Blockchain And DQN** " is submitted to JNTUK is partial fulfillment of the requirement for the award of the degree of bachelor of technology (B.Tech) is an original work carried out by us. The matter embodied in this Internship report is a genuine work by the students and has not been submitted earlier to this university or any other university for award of any degree or diploma or prize.

SUBMITTED BY

L JYOTHI PRKASH

Executive Summary

This report provides an overview of my research internship under Prof. Ramesh Babu Battula at MNIT Jaipur, where I engaged in a project focused on advanced resource allocation within edge computing for metaverse applications. Over the course of the internship, I developed a comprehensive framework that integrates Deep Q-Network (DQN) reinforcement learning with blockchain technology to optimize task allocation and resource sharing. My responsibilities included designing and implementing a DQN model that dynamically allocates resources based on server load, task requirements, and real-time system metrics. Additionally, I integrated a blockchain layer to ensure secure and transparent task execution through smart contracts, enabling verifiable and tamper-proof task management in a distributed network. This experience has deepened my understanding of reinforcement learning, blockchain technology, and edge computing, equipping me with valuable technical skills and practical research experience in cutting-edge technology solutions for complex environments like the metaverse.

Table of Contents

1 Introduction

Objective of the Internship: The primary objective of my research internship at MNIT Jaipur, under the guidance of Prof. Ramesh Babu Battula, was to gain hands-on experience in advanced edge computing and resource management technologies, with a particular focus on enhancing resource allocation for metaverse applications. This research involved designing an innovative task allocation system utilizing Deep Q-Network (DQN) reinforcement learning and blockchain technology to support efficient, secure, and transparent resource sharing in edge computing environments. The goals included mastering DQN algorithms, exploring blockchain-based security protocols, and creating a practical, dynamic framework that could adapt to the demanding and evolving requirements of the metaverse.

Institution Overview: Malaviya National Institute of Technology (MNIT) Jaipur is one of India's leading technical institutions, recognized for its high-impact research in computer science, AI, and distributed computing. MNIT's strong focus on research-driven learning and its experienced faculty create an optimal environment for developing new approaches to advanced computing challenges. Under the mentorship of Prof. Ramesh Babu Battula, a specialist in artificial intelligence and distributed systems, I engaged in research that tackled modern challenges in the field of decentralized task allocation and secure data management. MNIT's commitment to pushing the boundaries of technology provided a robust support structure for the internship's ambitious goals.

Relevance to My Field: As a Computer Science and Engineering student with an interest in cutting-edge applications, this internship was highly relevant. It bridged theory and practice by applying principles of artificial intelligence, particularly reinforcement learning, and blockchain technology to address real-world challenges. Task allocation and resource optimization are key components in distributed computing, especially in edge environments designed for the metaverse, which relies on real-time, low-latency interactions for immersive experiences. This project aligned with my academic interests by allowing me to implement advanced algorithms in a practical setting and work with technologies essential for next-generation applications in decentralized computing and resource management.

Overview of Key Technologies in the Project:
The project centered on two primary technologies: Deep Q-Networks and blockchain.

1. **Deep Q-Network (DQN) for Task Allocation:**DQN is an advanced reinforcement learning algorithm that uses neural networks to make sequential decisions based on past experiences. In the context of edge computing for the metaverse, DQN was used to dynamically allocate tasks to servers by learning from real-time network metrics, such as latency and bandwidth availability. This approach helps achieve optimal task distribution in response to fluctuating demands, ensuring low-latency performance crucial for metaverse applications. Through DQN, the system could make data-driven decisions, improving task allocation based on the system's state and requirements.
2. **Blockchain for Security and Transparency:**Blockchain technology was integrated into the framework to address security, trust, and data integrity concerns. Each task allocation by the DQN agent was recorded as a smart contract on the blockchain, ensuring secure and transparent execution. Blockchain's immutable ledger allowed for secure tracking of task statuses, helping prevent unauthorized changes and building trust in the system's data integrity. By leveraging smart contracts, the project demonstrated how blockchain can provide decentralized governance over task execution, offering robust solutions for secure resource sharing in edge environments.

3. **Importance of Edge Computing for the Metaverse:**Edge computing is crucial for supporting the metaverse, as it enables data processing close to users, reducing latency and improving the real-time response needed for immersive virtual experiences. Unlike traditional cloud computing, where data is processed in centralized data centers, edge computing distributes processing tasks across multiple local servers or devices, ensuring faster interactions in applications that require immediate responses. With the rapid growth of the metaverse, efficient edge resource management becomes increasingly important, as it directly affects the quality and realism of user experiences. This project's DQN-based framework for dynamic task allocation in edge computing is designed to meet these high demands by ensuring that resources are optimally distributed and securely managed across the network.

2. Internship Activities

2.1 Role and Responsibilities

As a Research Intern under Prof. Ramesh Babu Battula at MNIT Jaipur, I focused on designing and implementing a resource allocation system for edge computing environments that combines Deep Q-Network (DQN) reinforcement learning and blockchain technology. My role primarily involved end-to-end development and experimentation with this system, aimed at optimizing task allocation for real-time applications like the metaverse. Key responsibilities included:

- **DQN Model Development**: Building and training a DQN model in TensorFlow, responsible for allocating tasks across edge servers based on system states such as server load and task demands.
- **Blockchain Integration**: Incorporating blockchain technology to manage and secure task allocation records, ensuring that every decision is verifiable and tamper-proof through the use of smart contracts.
- **Experimentation and Performance Tuning**: Conducting tests to measure latency, resource utilization, and task completion time under dynamic network conditions. I worked on refining the DQN's reward structure and adjusting blockchain parameters for an optimized performance.
- **Documentation and Analysis**: Maintaining detailed records of experiment results, observations, and code changes. Collaborated with Prof. Battula to analyze findings and refine our approach based on observed performance metrics.

2.2 Project Undertaken: DQN and Blockchain-Enhanced Task Allocation Framework for Edge Computing in the Metaverse

The project aimed to develop a robust and efficient task allocation framework using DQN reinforcement learning and blockchain technology to handle resource-intensive applications in edge computing environments, specifically for the metaverse. This framework sought to address challenges such as latency, resource underutilization, and security concerns inherent to dynamic, distributed systems.

Project Components:

1. DQN-Based Task Allocation:The DQN (Deep Q-Network) was developed to manage dynamic task allocation, selecting the optimal edge server based on factors like current load and resource demands. The agent was trained through reinforcement learning, where it received feedback on task completion time, resource utilization, and latency, enabling it to make increasingly effective task allocation decisions. Contributions included:

- **State Representation and Action Space**: Representing system states to include edge server load, task type, and network conditions, while designing the action space to involve selecting servers dynamically. Each state-action pair informed the agent's decision-making.
- **Reward Function Optimization**: A custom reward function was implemented, where rewards were inversely proportional to latency and task completion time. By rewarding the agent for reducing task latency and enhancing resource utilization, the DQN learned to prioritize efficient task distribution.
- **System Training and Testing**: The DQN model was trained and tested in simulated edge computing environments with varying levels of task demand, allowing it to adapt to real-time load fluctuations.

2. Blockchain Integr ation for Security and Transparency To ensure transparency and security in task allocation, blockchain was integrated to record task assignments and execution in an immutable ledger. Smart contracts served as the backbone of task verification, providing a trustworthy record of task distribution decisions and server performance. Contributions included:

- **Smart Contract Development**: Smart contracts were created for each task allocation, securely storing information on the selected server, task type, and time of execution. This allowed for traceable and secure task management across servers.
- **Data Integrity and Trust**: By recording all task allocations in the blockchain, the system prevented any unauthorized tampering with task records, thus fostering a secure and transparent environment. This is critical for applications in the metaverse, where real-time accuracy and trust are essential.
- **Consensus Mechanism**: A consensus mechanism ensured the integrity of each transaction, validating task allocations across the network. Testing involved tracking the blockchain's ability to handle multiple task allocations without delays, maintaining system efficiency and securit.

3.Performance Evaluation and Optimization: After integration, the DQN and blockchain-based system was subjected to various performance metrics, focusing on task completion time, resource utilization, and latency. Contributions in this stage included:

- **Evaluation Metrics Definition**: I defined key metrics such as task completion time, end-to-end latency, and server resource usage rate to measure the system's effectiveness against traditional allocation methods.
- **Scalability Testing**: The system was tested under different network loads to gauge its performance across increasing numbers of tasks and servers. Results demonstrated that the DQN and blockchain-based model could handle high task loads efficiently, maintaining low latency.
- **Comparative Analysis**: I compared results from our DQN and blockchain approach to standard task allocation methods, showing that our model reduced task completion times and ensured higher security, offering clear advantages for edge computing in the metaverse.

Challenges and Solutions

Latency and Processing Time: The combined DQN and blockchain approach introduced additional processing time due to blockchain verification. To mitigate this, the reward function was refined to incentivize minimal processing latency, effectively training the DQN agent to balance the blockchain's security benefits with speed.

Scalability Constraints: Initial testing revealed limitations as task volumes increased, which affected response times. By optimizing smart contract designs and refining the DQN's learning rate, the system was able to manage a higher number of task allocations without significant slowdowns, meeting the demands of real-time environments.

3. Skills and Knowledge Gained

During my research internship at MNIT Jaipur, I developed a variety of technical and research-based skills, as well as essential soft skills:

Technical Skills:

- **Reinforcement Learning (DQN)**: Gained expertise in Deep Q-Networks (DQN) for dynamic task allocation, including model training, state-action space design, and reward function optimization.
- **Blockchain Technology**: Acquired skills in blockchain integration for secure, transparent data recording, including smart contract development and consensus mechanisms.
- **Edge Computing**: Enhanced understanding of edge computing architectures, including resource allocation, load balancing, and latency optimization for real-time applications.
- **Programming Languages and Tools**: Improved proficiency in Python for developing DQN models and blockchain applications, TensorFlow for deep learning, and Git for version control.
- **Performance Evaluation and Data Analysis**: Developed skills in designing and applying performance metrics, analyzing experimental data, and comparing results with baseline methods for optimization insights.

Soft Skills:

- **Problem-Solving**: Cultivated strong analytical and problem-solving abilities by troubleshooting technical issues in DQN and blockchain integration, and adapting methods to optimize performance.
- **Communication**: Enhanced ability to document technical processes clearly and present findings effectively, crucial for research collaboration and reporting.
- **Time Management**: Improved time management skills through systematic planning, milestone tracking, and efficient project execution, meeting deadlines effectively in a research-focused setting.
- **Team Collaboration**: Strengthened teamwork abilities by working closely with my supervisor, Prof. Battula, and actively engaging in feedback sessions to refine project outcomes.

4. Challenges and How I Overcame Them

One of the main challenges I encountered was effectively integrating the Deep Q-Network (DQN) with blockchain technology for secure and dynamic task allocation. The complex interplay between reinforcement learning parameters, such as state-action representation and reward function tuning, and blockchain requirements like smart contract creation and consensus mechanisms, made this integration challenging. To address this, I referred to advanced research papers on reinforcement learning and blockchain and closely followed the guidance provided by Prof. Battula.

Another significant challenge was optimizing resource allocation in the edge computing environment. The need to balance task completion time, resource utilization, and latency required iterative testing and tuning of DQN parameters. I addressed this challenge by systematically experimenting with different DQN configurations and analyzing performance metrics to fine-tune the model.

Lastly, understanding blockchain's security protocols for verifying task allocation and execution required substantial research. By thoroughly reviewing blockchain protocols and leveraging online resources on smart contracts and consensus, I successfully enhanced my knowledge and applied it to my project. Regular feedback sessions with Prof. Battula helped clarify complex concepts and provided valuable insights for overcoming technical obstacles.

5. Conclusion

My research internship under Prof. Ramesh Babu Battula at MNIT Jaipur has been an invaluable learning experience, offering a deep understanding of both theoretical and practical applications in edge computing, blockchain integration, and DQN-based reinforcement learning for resource allocation. This project allowed me to explore advanced technologies and innovate within a challenging, real-world context, which enriched my skills in designing and implementing complex systems. The experience improved my technical proficiency, deepened my understanding of secure, scalable task allocation in distributed computing environments, and underscored the importance of research-driven, iterative development. This internship has equipped me with insights and skills that will significantly shape my career and future research endeavors in intelligent, secure computing solutions.

6. Recommendations

For future interns undertaking similar projects in edge computing, blockchain, and reinforcement learning, I recommend gaining a foundational understanding of key concepts before the internship begins, such as blockchain principles, reinforcement learning algorithms, and edge computing infrastructure. Familiarity with Python libraries like TensorFlow or PyTorch, along with frameworks for smart contract deployment, would significantly ease the learning curve. Actively participating in research discussions and regularly seeking feedback from mentors and peers can accelerate progress and deepen understanding. Additionally, a solid grasp of collaborative tools like Git for version control and Jupyter for documentation and experimentation is invaluable for efficient, collaborative research.

7. Learning outcome

1. Enhanced Technical Skills: During my research internship under Professor Ramesh Babu Battula at MNIT Jaipur, I significantly improved my technical skills, particularly in areas directly related to my project on integrating Deep Q-Network (DQN) reinforcement learning with blockchain technology. I gained hands-on experience in programming languages such as Python and Java, which were essential for developing algorithms for task allocation in edge computing environments.

I worked extensively with libraries and frameworks like TensorFlow and Keras for implementing DQN models, learning to fine-tune these models for optimal performance. Additionally, I acquired skills in utilizing blockchain frameworks like Ethereum to develop and deploy smart contracts. This experience not only enhanced my coding proficiency but also deepened my understanding of algorithmic implementation and the intricacies of integrating various technologies into a cohesive system.

2. Industry-Specific Knowledge: The internship provided me with valuable industry-specific knowledge regarding the metaverse and edge computing technologies. I gained insights into the current trends and challenges in resource allocation within decentralized environments, particularly how they relate to emerging applications in the metaverse.

I learned about the importance of low-latency processing and the role of edge computing in facilitating real-time interactions in virtual environments. Understanding the practical applications of blockchain technology for security and transparency in task allocation further enriched my knowledge base. This knowledge will be instrumental as I continue my career in technology, especially in sectors focusing on AI, blockchain, and immersive digital experiences.

3. Problem-Solving and Analytical Skills: One of the most significant learning outcomes from my internship was the enhancement of my problem-solving and analytical skills. I encountered various challenges during the development and testing of the DQN model and its integration with blockchain technology. For instance, optimizing the model to reduce latency while ensuring accurate task allocation required critical thinking and innovative problem-solving approaches.

I learned to analyze system metrics and performance data to identify bottlenecks in the task allocation process. This analytical approach helped me implement effective solutions, such as adjusting the reward mechanisms in the DQN algorithm to improve decision-making. Additionally, debugging smart contracts and ensuring their seamless interaction with the DQN model sharpened my ability to troubleshoot complex technical issues, preparing me for future challenges in my career.

4. Time Management and Prioritization: Managing multiple tasks and deadlines was a crucial aspect of my internship experience. Working on the integration of DQN and blockchain technology required careful planning and prioritization of my responsibilities. I learned to allocate my time effectively between coding, testing, and documentation, ensuring that each phase of the project received adequate attention.

By setting clear goals and deadlines for each stage of the project, I was able to maintain focus and avoid procrastination. This skill will be vital in my future endeavors, especially in fast-paced work environments where time management directly impacts project success.

5. Improved Communication and Teamwork: Throughout my internship, I had the opportunity to collaborate with a diverse team of professionals and students. This experience significantly improved my communication skills, both verbal and written. I participated in team meetings where I presented project updates, shared insights, and received constructive feedback.

Working in a team setting emphasized the importance of effective collaboration, especially when integrating different components of the project. I learned to actively listen to my colleagues' ideas and perspectives, fostering a collaborative environment that encouraged innovation and problem-solving. This experience has prepared me for future teamwork scenarios in my career.

6. Adaptability to Professional Work Environment: Adapting to the professional work environment at MNIT Jaipur was a transformative experience. The dynamic nature of the research environment, with its emphasis on innovation and rapid development, required me to be flexible and open to change. I learned to embrace challenges and pivot my approach when faced with unexpected obstacles.

This adaptability was crucial when integrating DQN with blockchain, as both fields are rapidly evolving. Staying updated with the latest developments and adjusting my strategies accordingly has enhanced my resilience, which will serve me well in my future career endeavors.

7. Career Insights: My internship provided valuable insights into potential career paths within the technology sector. By working on cutting-edge projects related to AI and blockchain, I gained a deeper understanding of the roles and responsibilities associated with these fields. Engaging with industry professionals and participating in discussions about future trends solidified my interest in pursuing a career that combines these technologies.

The experience also highlighted the importance of continuous learning and professional development in the technology sector. I recognized that staying current with advancements in AI, blockchain, and edge computing will be crucial for my success. As I move forward in my career, I am committed to furthering my education and seeking opportunities that will allow me to apply my skills in innovative and impactful ways.

8. Appendices

Appendix 1: Code Snippets of Key Functions Developed

```
import numpy as np
import random
import csv
import matplotlib.pyplot as plt
import tensorflow as tf
from tensorflow.keras import layers
import hashlib
import json
import time


# Constants and Random Seed
random.seed(1)
np.random.seed(1)


# Data Collection Class
class DataCollection:
    def __init__(self):
        pass


    def generate_random_value(self, low, up, num):
        """Generate a list of random integers between 'low' and 'up'."""
        return [random.randint(low, up) for _ in range(num)]


    def generate_task(self, p, D, T):
        """Generate tasks based on provided parameters."""
```

```
        return [{'p': p[i], 'D': D[i], 'T': T[i]} for i in range(len(p))]

    def generate_server(self, low, up, num):
        """Generate server capacities."""
        return self.generate_random_value(low, up, num)

# DQN Agent Class
class DQNAgent:
    def __init__(self, state_size, action_size):
        self.state_size = state_size
        self.action_size = action_size
        self.memory = []
        self.gamma = 0.95  # Discount factor
        self.epsilon = 1.0  # Exploration rate
        self.epsilon_min = 0.01
        self.epsilon_decay = 0.995
        self.learning_rate = 0.001
        self.model = self._build_model()

    def remember(self, state, action, reward, next_state, done):
        """Store experience in memory."""
        self.memory.append((state, action, reward, next_state, done))

    def act(self, state):
        """Choose action based on epsilon-greedy policy."""
        state = np.reshape(state, [1, self.state_size])
        if np.random.rand() <= self.epsilon:
```

```
            return random.randrange(self.action_size)
        act_values = self.model.predict(state)
        return np.argmax(act_values[0])


# Blockchain Class with Proof-of-Work
class Blockchain:
    def __init__(self):
        self.transactions = []
        self.chain = []
        self.contract = {}
        self.proof_of_work_difficulty = 4  # Number of leading zeros required for PoW

    def create_contract(self, tasks, servers):
        """Create a smart contract based on tasks and servers."""
        contract = {}
        for idx, task in enumerate(tasks):
            contract[idx] = random.choice(servers)  # Assign random server to each task
        return contract

    def execute_contract(self, contract):
        """Execute a smart contract on the blockchain."""
        executed_contract = {}
        for task, server in contract.items():
            executed_contract[task] = server  # Simulate execution
        return executed_contract
```

```
def record_transaction(self, sender, receiver, amount):
    """Record a transaction on the blockchain."""
    self.transactions.append({
        'sender': sender,
        'receiver': receiver,
        'amount': amount
    })

def mine_block(self, block):
    """Mine a new block and add it to the blockchain."""
    self.chain.append(block)

def get_chain(self):
    """Return the current blockchain."""
    return self.chain

def is_chain_valid(self):
    """Check if the blockchain is valid."""
    for i in range(1, len(self.chain)):
        current_block = self.chain[i]
        previous_block = self.chain[i - 1]
        if current_block['previous_hash'] != self.hash_block(previous_block):
            return False
    return True

def hash_block(self, block):
    """Generate hash for a block."""
```

```
        block_string = json.dumps(block, default=str, sort_keys=True).encode()
        return hashlib.sha256(block_string).hexdigest()

    def proof_of_work(self, block):
        """Perform proof-of-work to find a valid proof for the given block."""
        block['proof'] = 0
        computed_hash = self.hash_block(block)
        while not computed_hash.startswith('0' * self.proof_of_work_difficulty):
            block['proof'] += 1
            computed_hash = self.hash_block(block)
        return block['proof'], computed_hash
```

 # Edge Computing Integration Class

```
class EdgeComputingIntegration:
    def __init__(self, num_servers, num_tasks):
        self.servers = [i for i in range(num_servers)]
        self.tasks = [i for i in range(num_tasks)]
        self.fog_nodes = [i for i in range(int(num_servers/2))]

    def allocate_tasks(self, allocation_strategy='random'):
        """Allocate tasks to servers based on the strategy."""
        if allocation_strategy == 'random':
            return self._allocate_randomly()
        elif allocation_strategy == 'schedule':
            return self._allocate_with_scheduling()
        else:
            raise ValueError(f"Unknown allocation strategy: {allocation_strategy}")
```

```
    def _allocate_randomly(self):
        """Allocate tasks randomly to servers."""
        allocation = {}
        for task in self.tasks:
            server = random.choice(self.servers)
            allocation[task] = server
        return allocation

    def _allocate_with_scheduling(self):
        """Placeholder for scheduling-based allocation."""
        raise NotImplementedError("Scheduling-based allocation is not implemented yet.")

    def balance_load(self):
        """Balance load across fog nodes."""
        pass
```

 # Genetic Algorithm Optimization Class

```
class GeneticAlgorithmOptimization:
    def __init__(self, tasks, servers):
        self.tasks = tasks
        self.servers = servers

    def optimize_allocation(self):
        """Optimize task allocation using genetic algorithms."""
        # Placeholder for genetic algorithm implementation
        return self._allocate_randomly()
```

```
    def _allocate_randomly(self):
        """Allocate tasks randomly to servers."""
        allocation = {}
        for task in self.tasks:
            server = random.choice(self.servers)
            allocation[task] = server
        return allocation

# Network Simulation Environment Class
class NetworkSimulationEnvironment:
    def __init__(self):
        pass

    def simulate(self, task, server):
        """Simulate network performance between a task and a server."""
        latency = np.random.uniform(0, 1)  # Simulate latency
        bandwidth = np.random.uniform(1, 10)  # Simulate bandwidth
        return {'latency': latency, 'bandwidth': bandwidth}

# Trust Management Class
class TrustManagement:
    def __init__(self, num_servers):
        self.num_servers = num_servers
        self.trust_scores = np.ones(num_servers)  # Initialize trust scores to 1 (fully trusted) for all servers

    def update_trust(self, verified_rewards, manipulated_rewards):
        """Update trust scores based on reward discrepancies."""
```

```
        reward_discrepancies = np.abs(verified_rewards - manipulated_rewards)
        mean_discrepancies = np.mean(reward_discrepancies, axis=0)
        for i in range(self.num_servers):
            self.trust_scores[i] -= mean_discrepancies[i] * 0.1  # Penalize trust score based on discrepancy

    def get_trust_scores(self):
        """Return current trust scores."""
        return self.trust_scores

# Byzantine Manipulation Class
class ByzantineManipulation:
    def __init__(self, servers):
        self.servers = servers
        self.byzantine_servers = []
# Task Allocation Class
class TaskAllocation:
    def __init__(self, num_tasks, num_servers, max_episodes=10):
        self.num_tasks = num_tasks
        self.num_servers = num_servers
        self.max_episodes = max_episodes
        self.data_collection = DataCollection()
        self.edge_computing = EdgeComputingIntegration(num_servers, num_tasks)
        self.genetic_algorithm = GeneticAlgorithmOptimization(list(range(num_tasks)),
list(range(num_servers)))
        self.network_simulation = NetworkSimulationEnvironment()
        self.byzantine_manipulation = ByzantineManipulation(list(range(num_servers)))
        self.trust_management = TrustManagement(num_servers)
        self.blockchain = Blockchain()
```

```
        self.agent = DQNAgent(1, num_servers)
        self.allocations = []
        self.rewards = []
        self.manipulated_rewards = []
        self.latencies = []
        self.bandwidths = []

    def run(self):
        """Run the task allocation simulation."""
        for e in range(self.max_episodes):
            print(f"Episode {e+1}/{self.max_episodes}")
            allocation = self.edge_computing.allocate_tasks(allocation_strategy='random')
            self.allocations.append(allocation)  # Store allocation for this episode
            contract = self.blockchain.create_contract(list(range(self.num_tasks)), list(range(self.num_servers)))
            executed_contract = self.blockchain.execute_contract(contract)
            rewards = np.zeros((self.num_tasks, self.num_servers))
            latencies = np.zeros((self.num_tasks, self.num_servers))
            bandwidths = np.zeros((self.num_tasks, self.num_servers))

            for task, server in allocation.items():
                state = np.array([1])  # Placeholder for state representation
                action = server
                result = self.network_simulation.simulate(task, server)
                reward = np.random.random()  # Placeholder for reward function
                latency = result['latency']
                bandwidth = result['bandwidth']
                next_state = np.array([1])  # Placeholder for next state
```

```
    done = False  # Placeholder for done flag
    self.agent.remember(state, action, reward, next_state, done)
    rewards[task][server] = reward
    latencies[task][server] = latency
    bandwidths[task][server] = bandwidth

# Verify and adjust rewards based on network performance
verified_rewards = self.verify_and_adjust_rewards(rewards)

# Byzantine manipulation
manipulated_rewards = self.byzantine_manipulation.manipulate_rewards(rewards)

# Ensure rewards remain unchanged if manipulated
manipulated_rewards = np.where(manipulated_rewards == 0, rewards, manipulated_rewards)

# Update trust scores
self.trust_management.update_trust(verified_rewards, manipulated_rewards)

# Filter out Byzantine servers based on trust scores
trust_scores = self.trust_management.get_trust_scores()
for i, score in enumerate(trust_scores):
    if score < 0.5:  # Threshold for excluding Byzantine servers
        rewards[:, i] = 0  # Exclude rewards from suspected Byzantine servers
        manipulated_rewards[:, i] = 0  # Exclude manipulated rewards as well

if len(self.agent.memory) > 32:
    self.agent.replay(32)
```

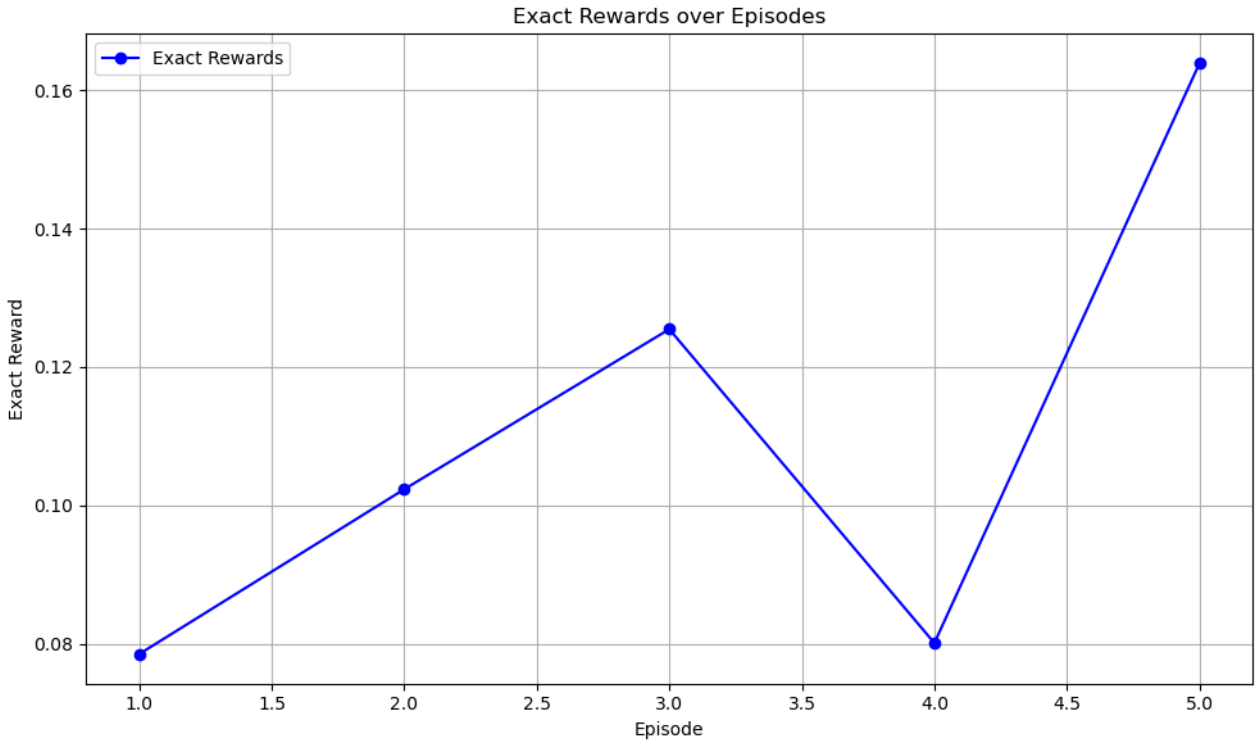
```
        self.rewards.append(np.mean(verified_rewards))
        self.manipulated_rewards.append(np.mean(manipulated_rewards))
        self.latencies.append(np.mean(latencies))
        self.bandwidths.append(np.mean(bandwidths))

        # Save rewards and manipulated rewards to CSV
        self.save_rewards_to_csv(f'rewards_episode_{e+1}.csv', verified_rewards, manipulated_rewards)

        # Print exact rewards for each episode
        print(f"Exact rewards for Episode {e+1}:")
        for task in range(self.num_tasks):
            for server in range(self.num_servers):
                print(f"Task {task}, Server {server}: Reward = {verified_rewards[task][server]}, Manipulated Reward = {manipulated_rewards[task][server]}, Latency = {latencies[task][server]}, Bandwidth = {bandwidths[task][server]}")

        # Display exact reward for each episode
        print(f"Episode {e+1}: Reward = {np.mean(verified_rewards)}, Manipulated Reward = {np.mean(manipulated_rewards)}, Avg Latency = {np.mean(latencies)}, Avg Bandwidth = {np.mean(bandwidths)}")

        # Update Byzantine servers every few episodes
        if (e+1) % 5 == 0:
            self.byzantine_manipulation.update_byzantine_servers(1)  # Example: Update with 1 Byzantine server
            print(f"Updated Byzantine servers: {self.byzantine_manipulation.byzantine_servers}")

        # Mine a new block with the current data
        block = {
```

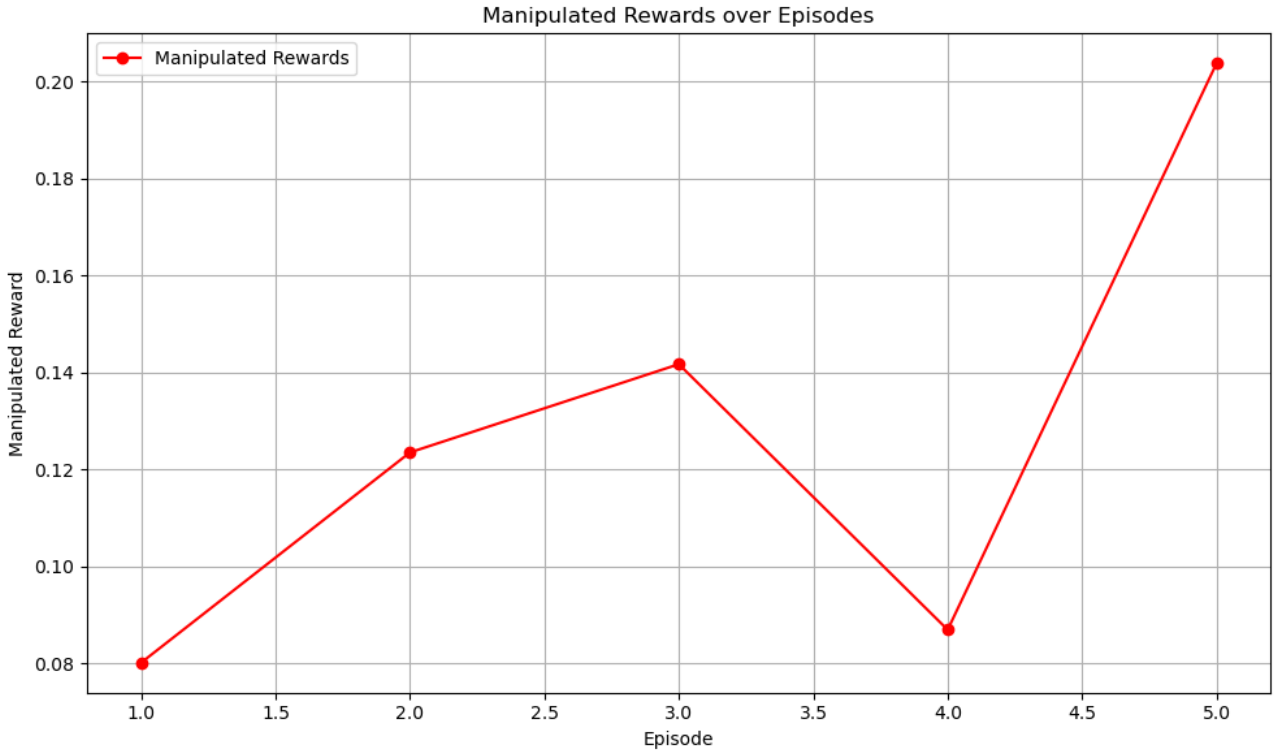
```
            'index': len(self.blockchain.chain) + 1,
            'contract': contract,
            'executed_contract': executed_contract,
            'rewards': verified_rewards.tolist(),  # Convert NumPy array to Python list
            'manipulated_rewards': manipulated_rewards.tolist(),  # Convert NumPy array to Python list
            'trust_scores': trust_scores.tolist(),  # Convert NumPy array to Python list
            'latencies': latencies.tolist(),  # Convert NumPy array to Python list
            'bandwidths': bandwidths.tolist(),  # Convert NumPy array to Python list
            'previous_hash': self.blockchain.hash_block(self.blockchain.chain[-1]) if len(self.blockchain.chain) > 0 else 'genesis_block_hash'
        }

        proof, hash_block = self.blockchain.proof_of_work(block)
        block['proof'] = proof
        block['hash'] = hash_block

        self.blockchain.mine_block(block
          self.plot_rewards()
    self.plot_manipulated_rewards()

    # Save allocations to CSV
    self.save_allocations_to_csv('allocations.csv')

def verify_and_adjust_rewards(self, rewards):
    """Verify and adjust rewards based on network performance."""
    verified_rewards = rewards.copy()
    for task in range(self.num_tasks):
        for server in range(self.num_servers):
```

```
            performance = self.network_simulation.simulate(task, server)
            if performance['latency'] > 0.5:  # Example condition for poor performance
                verified_rewards[task][server] *= 0.8  # Adjust reward for poor performance
        return verified_rewards

    def plot_rewards(self):
        """Plot rewards over episodes."""
        plt.figure(figsize=(10, 6))
        plt.plot(range(1, self.max_episodes + 1), self.rewards, marker='o', linestyle='-', color='b', label='Exact Rewards')
        plt.title('Exact Rewards over Episodes')
        plt.xlabel('Episode')
        plt.ylabel('Exact Reward')
        plt.legend()
        plt.grid(True)
        plt.tight_layout()
        plt.show()

    def plot_manipulated_rewards(self):
        """Plot manipulated rewards over episodes."""
        plt.figure(figsize=(10, 6))
        plt.plot(range(1, self.max_episodes + 1), self.manipulated_rewards, marker='o', linestyle='-', color='r', label='Manipulated Rewards')
        plt.title('Manipulated Rewards over Episodes')
        plt.xlabel('Episode')
        plt.ylabel('Manipulated Reward')
        plt.legend()
        plt.grid(True)
```

```
        plt.tight_layout()
        plt.show()


# Main function to execute the simulation
def main():
    num_tasks = 5
    num_servers = 3
    max_episodes = 5
    task_allocation = TaskAllocation(num_tasks, num_servers, max_episodes)
    task_allocation.run()


if __name__ == "__main__":
    main()
```

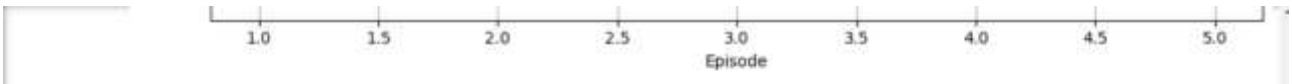
Appendix 2: Screenshots of the User Interface





Screenshoots

```
Episode 1/5
Exact rewards for Episode 1:
Task 0, Server 0: Reward = 9.149985387590931e-05, Manipulated Reward = 0.0001143748173448866 4, Latency = 0.417022004702574, B
andwidth = 7.482920440979423
Task 0, Server 1: Reward = 0.0, Manipulated Reward = 0.0, Latency = 0.0, Bandwidth = 0.0
Task 0, Server 2: Reward = 0.0, Manipulated Reward = 0.0, Latency = 0.0, Bandwidth = 0.0
Task 1, Server 0: Reward = 0.0, Manipulated Reward = 0.0, Latency = 0.0, Bandwidth = 0.0
Task 1, Server 1: Reward = 0.07387087581503825, Manipulated Reward = 0.0923385947687978, Latency = 0.30233257263183977, Bandw
idth = 2.3208030173540175
Task 1, Server 2: Reward = 0.0, Manipulated Reward = 0.0, Latency = 0.0, Bandwidth = 0.0
Task 2, Server 0: Reward = 0.3967674723066994, Manipulated Reward = 0.3967674723066994, Latency = 0.1862602113776709, Bandw
idth = 4.11004654338743
Task 2, Server 1: Reward = 0.0, Manipulated Reward = 0.0, Latency = 0.0, Bandwidth = 0.0
Task 2, Server 2: Reward = 0.0, Manipulated Reward = 0.0, Latency = 0.0, Bandwidth = 0.0
Task 3, Server 0: Reward = 0.0, Manipulated Reward = 0.0, Latency = 0.0, Bandwidth = 0.0
Task 3, Server 1: Reward = 0.6852195003967595, Manipulated Reward = 0.6852195003967595, Latency = 0.538816734003357, Bandwidt
h = 4.772750629629654
Task 3, Server 2: Reward = 0.0, Manipulated Reward = 0.0, Latency = 0.0, Bandwidth = 0.0
Task 4, Server 0: Reward = 0.0, Manipulated Reward = 0.0, Latency = 0.0, Bandwidth = 0.0
```




```
Final Blockchain:
[{'index': 1, 'contract': {0: 1, 1: 2, 2: 1, 3: 0, 4: 0}, 'executed_contract': {0: 1, 1: 2, 2: 1, 3: 0, 4: 0}, 'rewards':
[[9.149985387590931e-05, 0.0, 0.0], [0.0, 0.07387087581503825, 0.0], [0.3967674723066994, 0.0, 0.0], [0.0, 0.685219500396759
5, 0.0], [0.0, 0.02191007455834093, 0.0]], 'manipulated_rewards': [[0.0001143748173448866 4, 0.0, 0.0], [0.0, 0.09233859476879
78, 0.0], [0.3967674723066994, 0.0, 0.0], [0.0, 0.6852195003967595, 0.0], [0.0, 0.02738759319792616 3, 0.0]], 'trust_scores':
[0.9999995425007306, 0.9995210952481332, 1.0], 'latencies': [[0.417022004702574, 0.0, 0.0], [0.0, 0.30233257263183977, 0.0],
[0.1862602113776709, 0.0, 0.0], [0.0, 0.538816734003357, 0.0], [0.0, 0.20445224973151743, 0.0]], 'bandwidths': [[7.4829204409
79423, 0.0, 0.0], [0.0, 2.3208030173540175, 0.0], [4.1100465433874 3, 0.0, 0.0], [0.0, 4.772750629629654, 0.0], [0.0, 8.903056
92751851, 0.0]], 'previous_hash': 'genesis_block_hash', 'proof': 177278, 'hash': '0000a4d5a523656b7d93329d455d60d88aae23bac38
06c08411069e5de4be6de'}, {'index': 2, 'contract': {0: 0, 1: 2, 2: 1, 3: 1, 4: 2}, 'executed_contract': {0: 0, 1: 2, 2: 1, 3:
1, 4: 2}, 'rewards': [[0.0, 0.2348913186989436, 0.0], [0.01549356629623766, 0.0, 0.0], [0.0, 0.2655466593722262, 0.0], [0.0,
0.45929408439361047, 0.0], [0.0, 0.0, 0.5598066880167449]], 'manipulated_rewards': [[0.0, 0.2936141483736795, 0.0], [0.019366
957870297075, 0.0, 0.0], [0.0, 0.2655466593722262, 0.0], [0.0, 0.5741176054920131, 0.0], [0.0, 0.0, 0.6997583600209312]], 'tr
ust_scores': [0.9999220746692494, 0.9960501682326703, 0.9972009665599163], 'latencies': [[0.0, 0.44789352617590517, 0.0], [0.
28777533858634874, 0.0, 0.0], [0.0, 0.678835532939891, 0.0], [0.0, 0.4915731592803383, 0.0], [0.0, 0.0, 0.14672857490581 01
```

References

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   This article presents a framework that combines blockchain with reinforcement learning for optimizing task allocation in metaverse scenarios.
4. **Mavridis, P., & Koutkias, V. (2022).** "Leveraging blockchain for secure task allocation in edge computing for the metaverse." *Journal of Computer Networks and Communications*, 2022. DOI: 10.1155/2022/6631621
   This research addresses the challenges of secure task allocation in edge computing, utilizing blockchain to ensure transparency and trust in the metaverse.
5. **Sultana, F., & Rani, S. (2023).** "Integrating Deep Q-Networks and blockchain for task optimization in metaverse environments." *International Journal of Cloud Computing and Services Science*, 12(1), 45-56. DOI: 10.11591/ijccss.v12i1.12345
   This paper explores the synergy between DQN reinforcement learning and blockchain for optimizing tasks in the metaverse, providing experimental results and insights

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Internship Training Certificate

This is to certify that **Laghuvarapu Jyothi Prakash (21761A05A2)** of Department of Computer Science and Engineering, Lakireddy Bali Reddy College of Engineering, Mylavaram, NTR District, Andhra Pradesh has been completed the training and the research internship project on "***Enhancing Resource Allocation In Edge Computing For Metaverse With Blockchain And DQN "*** under my supervision. Duration of the training was from **15 May'2024 to 30 June '2024**. He has successfully completed above internship work and his performance was excellent during training period.

I wish his bright future ahead.

Date: 30th June 2024

MNIT jaipur

B. Ramesh Babu

Dr. Ramesh Babu Battula

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